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MLR Based Statistical Downscaling of Temperature and Precipitation in Lidder Basin Region of India

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Abstract

In the present study, the multiple linear regression technique was employed to relate the monthly predictors obtained from the Global Climate Model namely CGCM3 (Canadian Centre for Climate Modelling and Analysis) with the monthly Predictands such as the locally observed precipitation and temperature at Pahalgam meteorological station which is located in the Lidder River Basin. Appropriate predictand-predictor relationships were found out for the region by carrying out sensitivity analysis .Regression equations were developed and subsequently future monthly and annual projections for precipitation, maximum temperature and minimum temperature for the entire 21st century were made. It was observed that at the end of the 21st century the CGCM3 model predicted an increase of 18.07% annual precipitation, whereas the average maximum and minimum annual temperatures were predicted to increase by 0.62°C and 0.76°C, respectively.

Keywords: General circulation models; Downscaling; Multiple linear regression; Predictors

Introduction

Climate change has been defined as a "Change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" [1]. Downscaling techniques are used to bridge the spatial and temporal resolution gaps between what climate modellers are currently able to provide and what impact assessors require. GCM outputs are converted into local meteorological variables by different downscaling methods. Two fundamental approaches exist for downscaling of GCM outputs:

1. Dynamical downscales: the use of regional climate models (RCM) or limited-area models which use the lateral boundary conditions from a GCM to produce high resolution outputs [2].

2. Statistical downscaling: a range of methods which rely on the fundamental concept that regional climate is related to the large-scale atmospheric state, expressed as a deterministic and/or stochastic function between the large-scale atmospheric variables (predictors) and local or regional climate variables [3,4].

In the present study, the multiple linear regression technique was employed to relate the GCM predictors of Global Circulation Model namely the CGCM3 (Canadian Centre for Climate Modelling and Analysis) with the Predictands such as the locally observed monthly precipitation and temperature at Pahalgam meteorological Station located in the Lidder river basin. The predictors as obtained from the outputs of CGCM3 are mean sea level pressure (mslpas), mean air temperature at 2m (Tempas), relative humidity, short wave radiation, meridional velocity and zonal velocity. The relationships so developed were used to predict the future climate at the end of 21st century, in the form of monthly projections for precipitation and minimum and maximum temperatures.

Methodology

Study area

The Lidder valley has been carved out by River Lidder, a right bank tributary of River Jhelum. It has a catchment area of 1159.38 km² which constitutes about 10 per cent of the total catchment area of River Jhelum [5]. The steep slopes in the Lidder valley along with depleted forest cover have been major factors of and sedimentation. These factors have also affected the drainage pattern of Lidder stream significantly and made the system extremely fragile as it has started showing signs of degeneration. The catchment area of Lidder stream occupies the south eastern part of the Kashmir valley and is situated between 33º 45′ 01″ N-34º 15′ 35″ N and 74º 06′ 00″ E–75º 32′ 29″ E (Figure 1).The lidder basin has an elevation range from 1440 m-5385 m above sea level .It consists of some of the major tourists attractions in the form of Pahalgam (world famous resort), Lidder river, Aru, Sheeshnag lake and Marsar lake. The land use characteristics of the lidder basin are given in Table 1. The Lidder valley forms part of the western Himalaya and lies between the Pir Panjal range in the south, south-east, and southwest Zanskar range. The valley begins from the base of the two snow fields, the Kolahoi and Sheshnag where from its two main upper streams; the West and the East Lidder originate and join each other near the famous tourist spot Pahalgam town and finally joins the Jhelum at Gur village (Anantnag District).

Multiple linear regressions

The association of three or more variables can be investigated by the multiple regression and correlation analysis [6]. The multiple-regression relation may be expressed in the form of Eq.

$$x_1 = f(x_2, x_3, x_4 \ldots x_m) \tag{1}$$

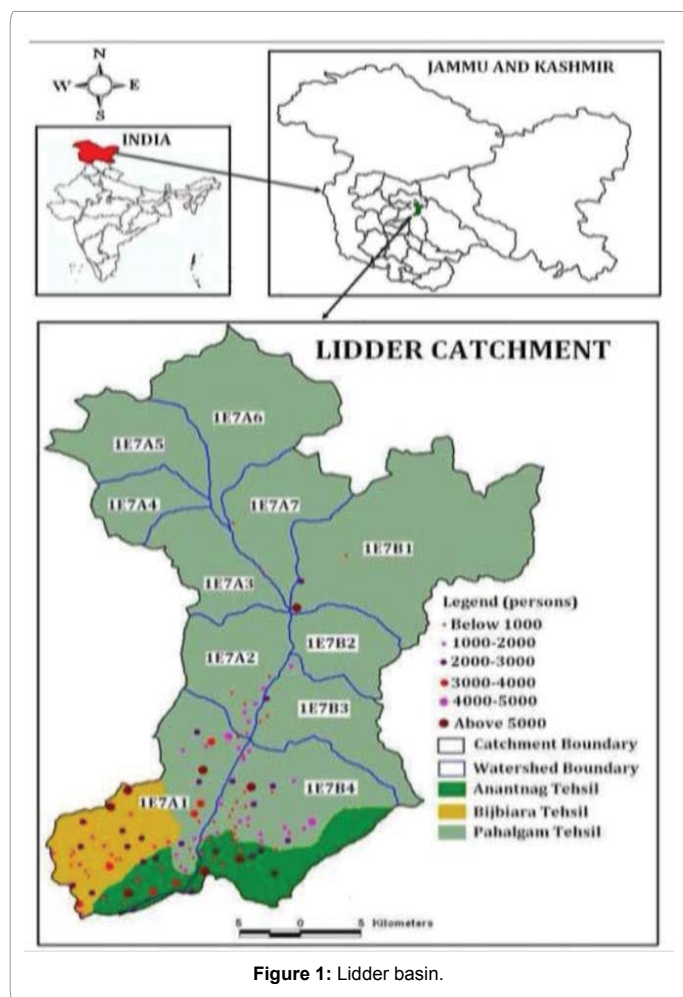where x_1, x_2, x_3, x_4,..., x_m are m variables.This equation gives the

Figure 1: Lidder basin.

S. No.	Description	Area (m²)
1	Settlements	13.82
2	Agriculture	150.513
3	Horticulture	79.826
4	Forest	322.136
5	Scrub	236.96
6	GrazingLand	31.3448
7	Wastelands	112.93
8	Wetlands	1.422
9	Waterbodies	21.51
10	Snow	287.21

Table 1: Land use characteristics of Lidder basin.

estimate of x_1 for given values of all other variables. If Eq. (1) is linear, the regression is referred to as multiple linear regressions and the association is multiple linear correlations.

Data analysis

The daily precipitation and temperature data at Pahalgam meteorological station of Lidder Basin for the period 1978-2014 were obtained from India meteorological Department (IMD) Srinagar. The predictor data of Mean sea level pressure (mslpas), mean air temperature at 2m (Tempas), relative humidity, specific humidity, short wave radiation, long wave radiation, meridonial velocity , wind speed mean

and zonal velocity were obtained for Global Circulation Model namely the CGCM3 for A1B scenario for the grid location of Area: 32.17°N 72.31°E to 37.05°N 80.20°E. The above mentioned predictor data for Global Circulation model CGCM3 was obtained for the year 1961-2100. For multiple linear regression (MLR) analysis the predictand data set for the period 1978-2010 were used for calibration and that of 2011-2014 were used for validation purposes. Sensitivity Analysis was carried out to find the predictor-predictand relationships and nine deseasonalized predictors and three deseasonalized predictands (monthly mean maximum and minimum temperatures, and total monthly precipitation) were used to investigate correlation coefficients among predictors and to evaluate their predictive ability when used in a multiple linear regression (MLR) downscaling model. Air temperature, relative humidity, meridonial velocity and zonal velocity at different levels were important explainable predictors for the daily maximum and minimum temperatures. Mean sea level pressure (Mslpas), Tempas (mean air temp at 2m), relative humidity and short wave radiation were explanatory predictors for precipitation. The relationship of maximum and minimum temperature, precipitation with the appropriate predictors was expressed by regression equations in the form of Eq. (2),

$$y = a_1 X_1 + a_2 X_2 + a_3 X_3 + \cdots + a_n X_n \qquad (2)$$

Where y=Predictands (Local station Max. Temp, Min. Temp. and Precipitation) and X_1, X_2, X_3 …X_n are different GCM predictors.

Results and Discussion

The observed data sets of mean monthly maximum and minimum temperatures and total monthly precipitation for the period 1978 to 2010 were used for calibration purposes, that is, to establish the regression equations. The validation of these regression equations was carried out using the monthly predictand data sets for the years 2011 to 2014. The results of validation are shown in Figure 2a shows the comparison between observed and predicted values of monthly precipitation using Global Circulation Model CGCM3 at Pahalgam meteorological observatory located in Lidder river basin. Figures 2b and 2c show that there is an excellent comparison between observed monthly mean maximum and minimum temperatures and those predicted by using regression equations of Table 2, for the validation period of 2011 to 2014.The regression relationships developed above, were used to predict the monthly precipitation, monthly mean maximum and minimum temperatures at Pahalgam meteorological observatory over the entire 21st century. These 100 year monthly projections of local weather parameters at Pahalgam are shown in Figures 3-5.

From Figure 3 It can be found out that the precipitation predicted by CGCM3 model showed an increasing trend for the months of March, May, August, September, October and December while as it showed decreasing trend for the months of January, February, April, June, July and November. The monthly mean maximum and minimum temperature as predicted by Global Circulation model CGCM3 for A1B scenario during 21st century are shown in Figures 4 and 5. This paper examines the applicability of MLR approach as a downscaling procedure for downscaling mean monthly maximum temperature,

GCM Model	Change in Precipitation %	Max. Temp Change (°C)	Min. Temp Change (°C)
CGCM3	+18.07	+0.62	+0.76

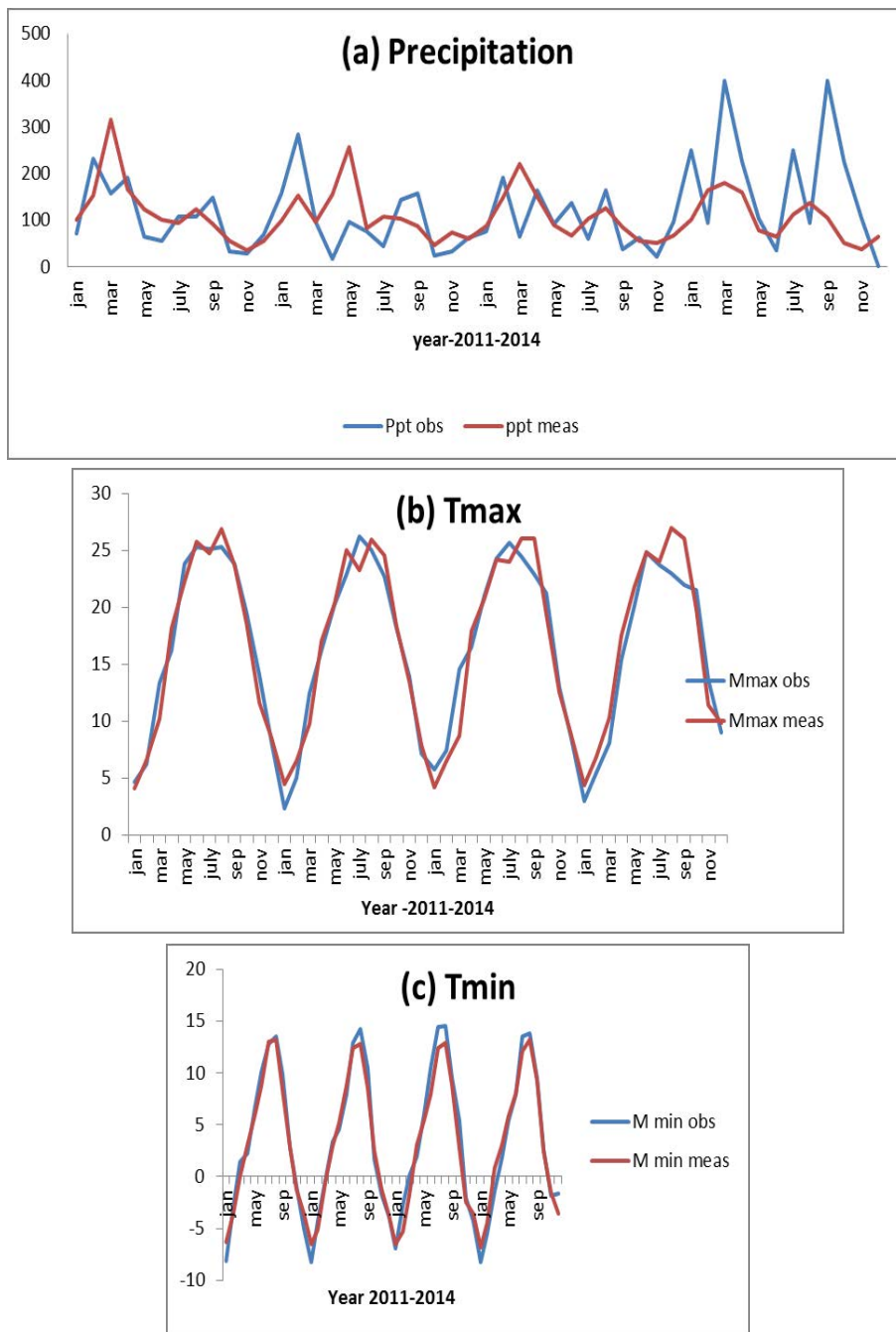**Table 2:** Variation of annual weather parameters at Pahalgam station of Lidder river basin during 21st century.

Figure 2: Validation of (a) Precipitation (b) T_{max} (Mean monthly maximum temperature) (c) T_{min} (Mean monthly minimum temperature) at Pahalgam for the period 2011-2014.

Minimum Temperature and precipitation from GCM outputs to local scale. The viability of this model is shown through the application in Lidder river basin region of west Himalayan region of India. The average annual maximum and minimum temperature showed an increase of 0.62°C and 0.76°C, respectively during the course of 21st century which is shown in Figure 6.
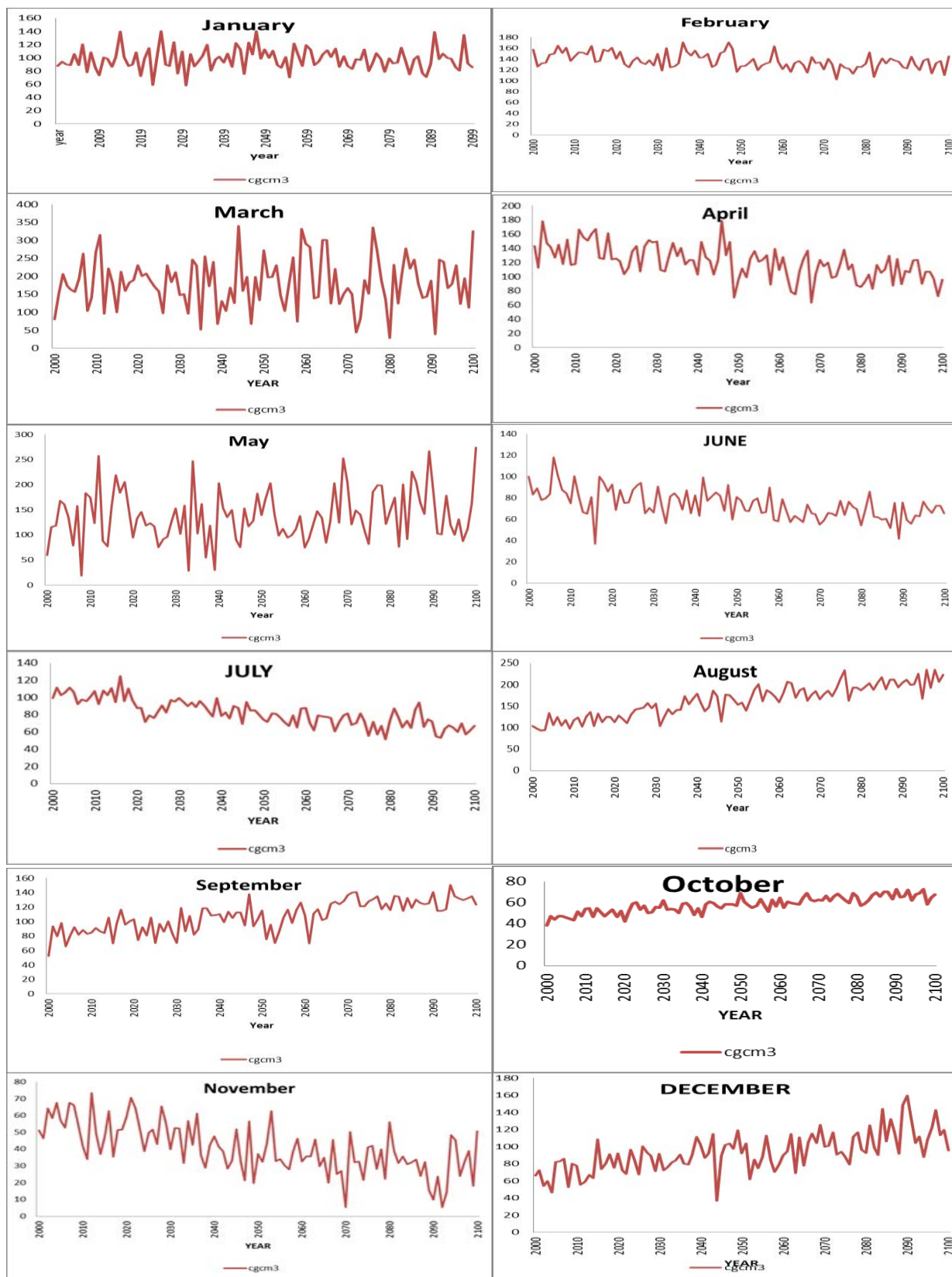
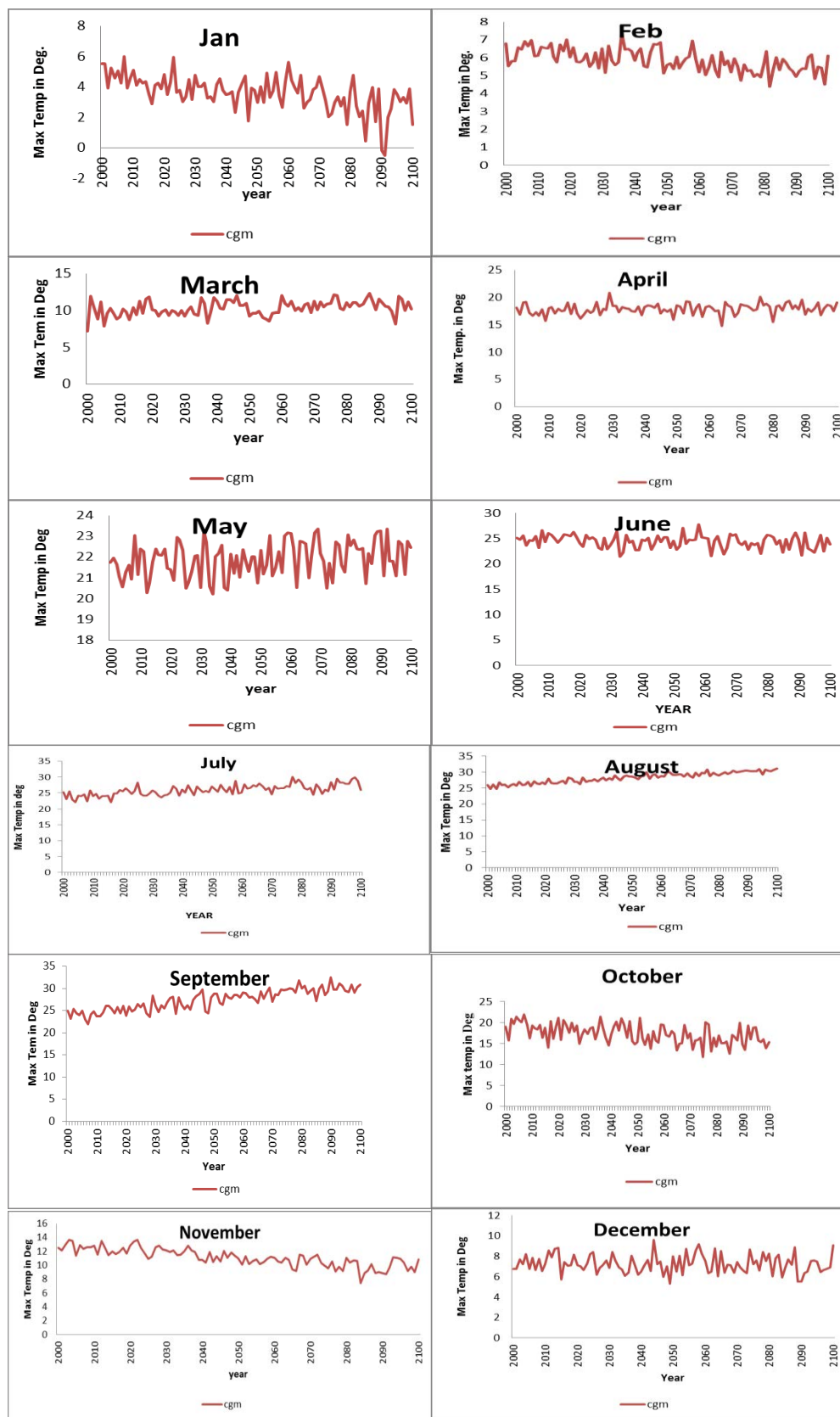**Figure 3:** Variation of precipitation at Pahalgam during 2001-2100.

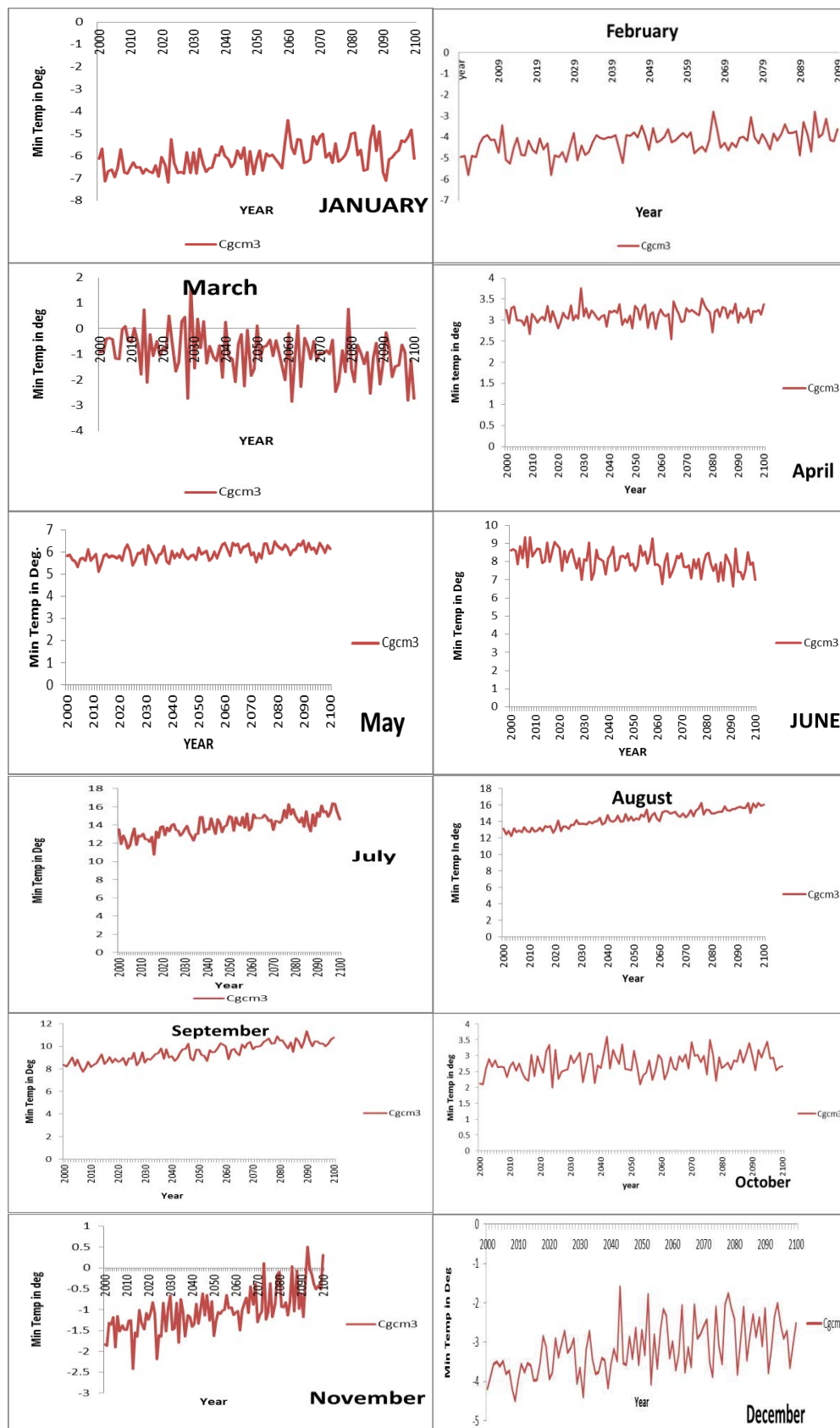**Figure 4:** Variation of monthly mean maximum temperature at Pahalgam during 2001-2100.

Figure 5: Variation of monthly mean minimum temperature at Pahalgam during 2001-2100.

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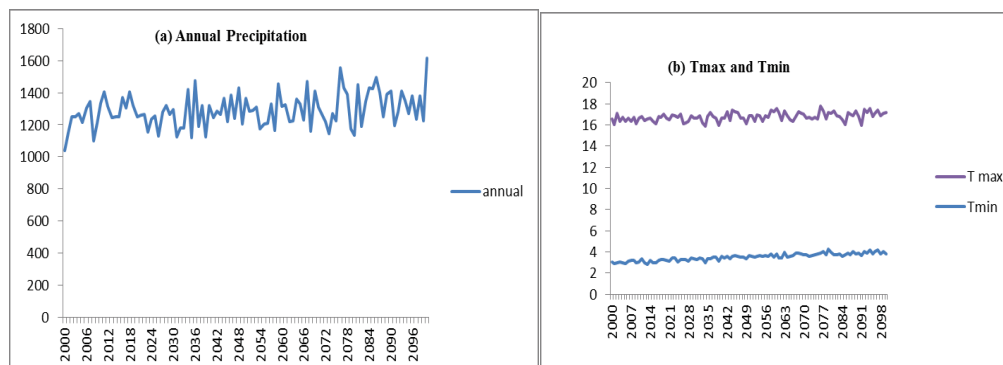
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Figure 6: Variation of (a) total annual precipitation (b) average annual maximum temperature and average annual minimum temperature of Lidder river basin during 21st century.

Conclusion

From the analysis of results, the following conclusions were drawn:

It was found out that the precipitation for CGCM3 model showed an increasing trend for the months of March, May, August, September, October and December while as it showed decreasing trend for the months of January, February, April, June, July and November . The maximum and minimum temperatures showed an increasing annual trend of 0.62 and 0.76 degrees, respectively during the course of 21st century and precipitation was found to be increasing by 18.07% annually. In order to reduce the discrepancy, different downscaling techniques can be used and further more GCMs and different scenarios can be used.

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